

# Solar Sources Working Group

## *Sub-group 1*

**3He Rich Events / Sources:** Examine source characteristics of the small  $^3\text{He}$ -rich SEP events associated with flares. How do they differ from those of the large SEP events under investigation? Bonus question: Do they distinguish themselves from other impulsive (flare) acceleration events?

Mike Kaiser \*

Seiji Yashiro \*

Neal Hurlburt

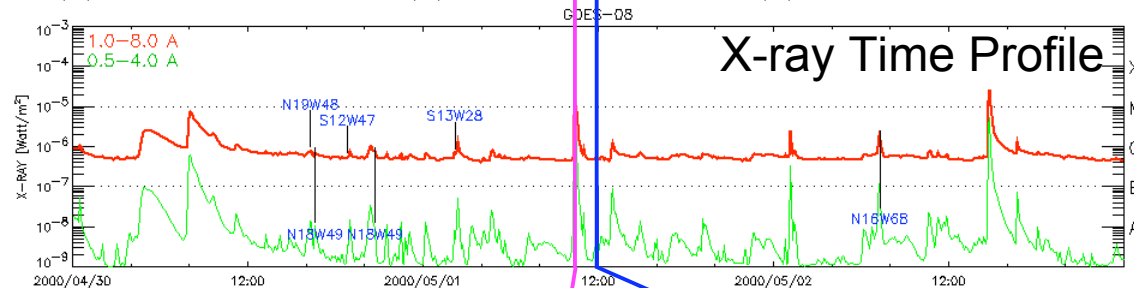
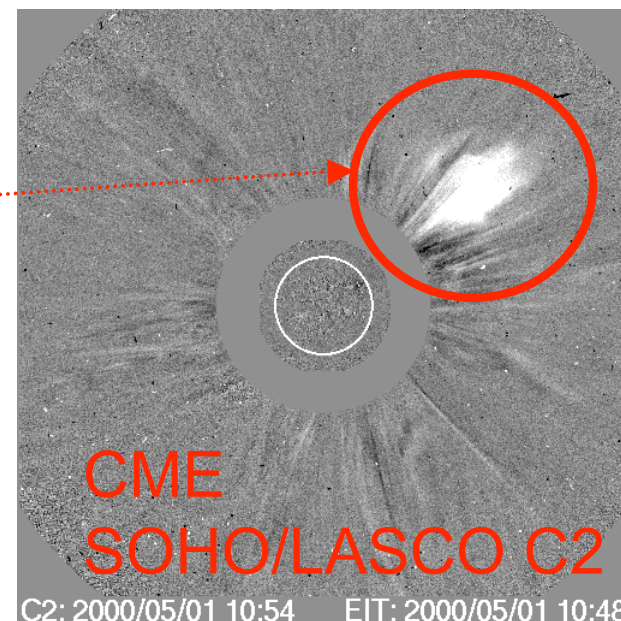
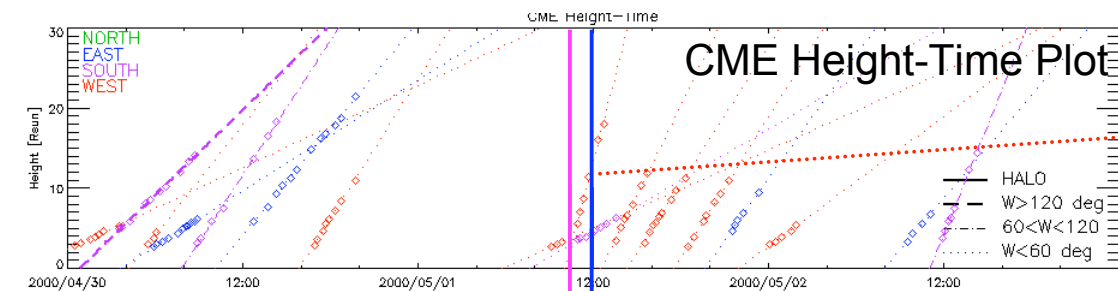
Don Reames

Masumi Shimojo

Barbara Thompson

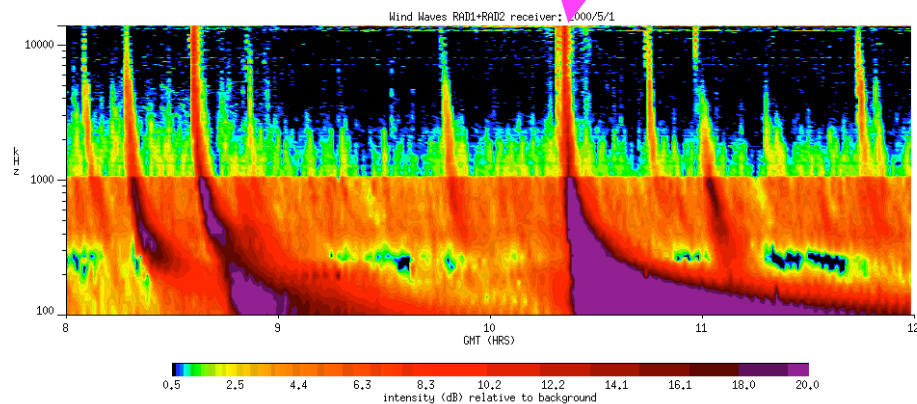
Context/Summary: In the current two-class picture of solar energetic particle events (Reames, 1999), impulsive (flare) SEP events lack CMEs and shocks. Recently, however, Kahler et al. (2002) reported several flare SEP events that had associated CMEs. During the workshop, Yashiro, Shimojo, and colleagues found that approximately two-thirds of a sample of  $^3\text{He}$ -rich events identified by Don Reames had associated CMEs, although type-II (shock) association remained low ( $\sim 5\%$ ).

# 2000/05/01 He<sup>3</sup>-Rich Event

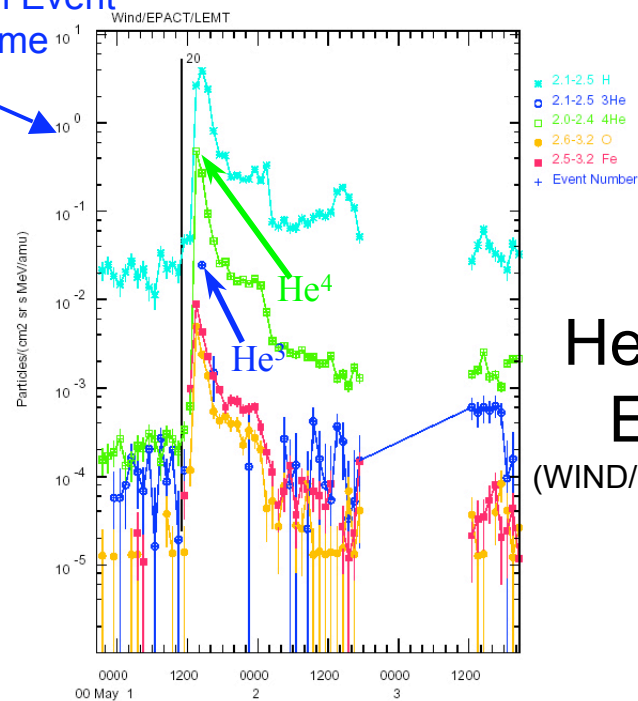


Start Time of  
Solar Source

He<sup>3</sup>-rich Event  
Start Time



Interplanetary Type III Radio Burst  
(WIND/WAVES)



He<sup>3</sup>-Rich  
Event  
(WIND/EPACT/LEMT)

# 3He-Rich SEPs

Western CME Associations: 24/36 (67%)  
(1.5 hour time window)  
(2 out of 38 lacked LASCO data)

Median Speed: 560 km/s

Median Width: 55 degree

Metric Type II Associations: 2/38 (5%)  
(30 min time window)

Solar Source Location

Only 14 events were identified.

Median Longitude: W63

An interesting aspect of this study was the identification of several small CMEs that were not identified in the original search of LASCO data.

## *Sub-group 2*

**Type III I's & SEPs:** Examination of novel SEP acceleration signature. Are electron accelerators also proton accelerators?

**Bob MacDowall\***

**Alejandro Lara**

**P.K. Manoharan**

**Nariaki Nitta**

**Ana Rosas**

Context/Summary: Cane, Erickson, and Prestage (2002) identified a new type of radio type II burst designated type III L where L indicates late starting, longer lasting, and existing to lower frequencies. Type III bursts are associated with electrons in space and Cane et al. find that the type III L events are also associated with energetic proton events. Using an operational definition of type III I's, MacDowall and co-workers substantiated the results of Cane et al.

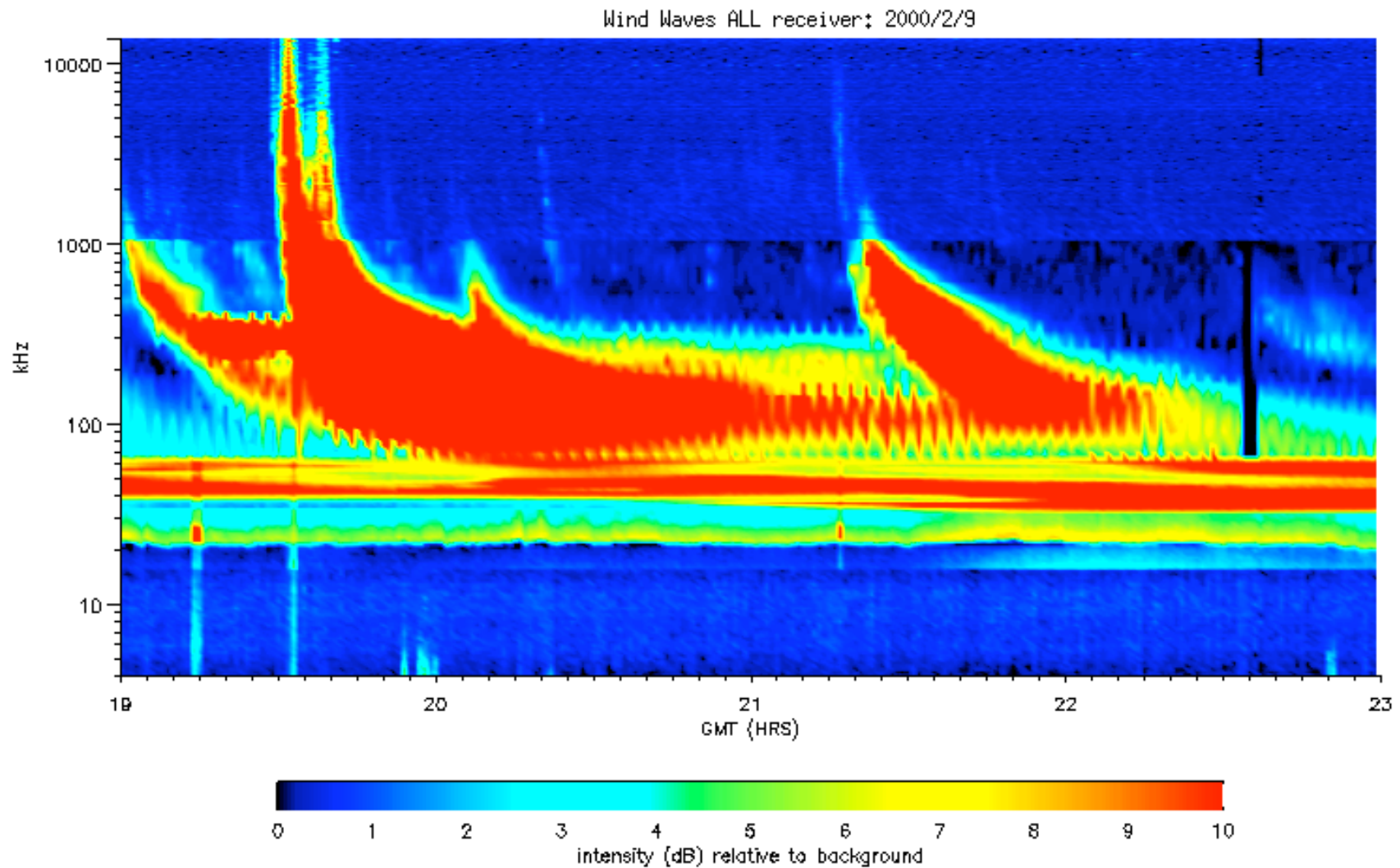
# Characteristics of type III-L bursts

(L = longer, lower freq., later)

- Type III burst variant discussed by Cane et al., 2001
- Commence or extend beyond 5-10 min after start of flare (at or above 10 MHz)
- Usually commence at frequencies higher than associated type II burst
- Dominant feature in the dynamic spectra of (Wind Waves) radio events associated with solar energetic particles (HVC says focus on on RAD1 DS)
- Only occur in association with proton acceleration at Sun
- Large CME is not sufficient for occurrence of a type III-L

Note: “Flare” = “sudden energy release in the solar atmosphere”  
(Hudson et al., 1995)

# Wind Waves example of (weak) type III-L radio burst (only type III-L in control group #1)



# Main points of Cane et al., 2002

- Essentially all proton events ( $> 20$  MeV) preceded by type III-L radio bursts [121 out of 123 events]
- Causative electrons UNLIKELY to be shock accelerated; suggested that origin is in reconnection regions below fast CME.
- Existence of type IIIs shows that OPEN field lines exist from flaring regions; therefore, SEPs can escape from flare region
- CMEs w/o type III-Ls do not produce  $>20$  MeV protons

# Questions/corroborations

- Do all LWS CDAW SEP events have type III-Ls?
- Do control groups w/o SEPs have type III-Ls? (note that magnetic connection is required for SEPs at “Earth”)
- Is there a consistent type III-L – SEP connection that has operational significance?
- Are there subclasses of type III-Ls that we can identify?
- What are the characteristics of type III-Ls that make them unique?



# Operational definition of type III-L

- Fast drift 1 MHz radio event in Wind Waves RAD1 data ends at least 10 minutes after flare start (H-alpha or SXR) (14 MHz in Cane et al., 2002, BUT, we use 1 MHz because limb events are frequently occulted above ~2 MHz)
- In lieu of flare start time, the start time of the Waves radio event may be used.
- Wind Waves intensity greater than 10 dB above background at 100 kHz. This ensures an intense event that extends to lower frequencies.
- Note: Examination of meter wavelength dynamic spectra is useful for further clarification, permitting rejection of unrelated groups of “normal” type III bursts.

# Type III-L burst statistics – 1 MHz

	1 MHz type III-L burst	NO 1 MHz type III-L	Ambiguous/ data gap
CDAW SEP events (total=46)	45 (97.8%)	1 (2.2%) May 7, 2001	0/1
Control #1 SXR flares $\geq$ M3.0, $\geq$ W30, NO SEPs $\geq 10^{-3}$ @20 MeV (total=26)	1 (4.4%)	22 (95.6%)	1/2
Control #2 Fast CMEs $\geq 700$ km/s, NO SEPs $> 10^{-3}$ @20 MeV (total=20)	4 (26.7%)	11 (73.3%)	3/2

# Type III-L burst statistics – 14 MHz

	14 MHz type III-L burst	NO 14 MHz type III-L	Ambiguous/ (data gap)
CDAW SEP events (total=48)	28 (62.2%)	17 (37.8%)	0/3
Control #1 SXR flares $\geq$ M3.0, $\geq$ W30, NO SEPs $\geq 10^{-3}$ @20 MeV (total=26)	0 (0%)	23 (100%)	1/2
Control #2 Fast CMEs $\geq 700$ km/s, NO SEPs $> 10^{-3}$ @20 MeV (total=20)	1 (5.6%)	17 (94.4%)	0/2

# Summary

- An “operational” definition of the type III-L radio burst has been obtained
- It identifies 98% of the CDAW SEP events (using 1 MHz to define the radio duration)
- “False positive” identification as type III-L occurs for only 13% of the control groups (combined); this error rate can be reduced by using higher frequency radio data (ground-based).
- Although successful as an SEP proxy, more analysis is required to understand the physical differences between acceleration of III-L electrons and those of “simple” type III bursts

# Post Workshop Addendum

- At the end of the workshop, a comment was made that many events on the workshop 3-He list would satisfy the type III-L “operational definition”.
- To the extent that this is correct, the “operational definition” is inadequate, because the majority of type III-L events (associated with the workshop SEP list) clearly “look different” from type III radio bursts associated with 3-He events.
- The first step towards a better definition is to define duration better, e.g., duration at 10% of the peak flux. This will be done for the workshop paper.
- A second step may require characterization of the number of components in the event; this issue has been discussed extensively for SA events (a name used previously for type III-L bursts). See MacDowall et al., *Solar Physics*, 111, 397\_418, 1987.

### ***Sub-group 3***

**Interacting CMEs:** Examination of novel SEP acceleration signature. How do colliding CMEs or shocks alter the abundances? The spectra? Are there any features in the SEPs that coincide with the times of CME collisions?

**Ian Richardson \***

**Terry Kucera**

**Gareth Lawrence**

**Mike Reiner**

**Adam Szabo**

Context/Summary: Gopalswamy et al. (ApJ Lett 572, L103, 202) reported that CME interaction is a good discriminator between SEP-poor and SEP-associated CMEs. In contrast, Richardson and coworkers on this subgroup concluded that SEP events are unlikely to be the result of CME interactions.

## Interacting CME Analysis:

Examined 6 largest SEP events, then other events, for evidence of CME interaction in LASCO observations. No compelling cases. Reasons e.g.,

- Preceding CME originated far from primary CME location - Physical interaction unlikely;
- Preceding CME disappears into background corona within a few  $R_s$ . - Unlikely to provide dense material to enhance shock driven by primary CME;
- CME leading edge height-time profiles intersect at large distances/ after SEPs are already visible at Earth (Primary CME is typically at low altitude  $\sim 2 R_s$  at SEP onset).
- Suggested streamer interaction for 4 November 2001 unlikely – streamers probably backside.
  - \* Though two CMEs overlap in projection, there is no clear evidence that they do interact (e.g., no deflection, disruption).

Examined WIND/WAVES radio data for all events to identify signatures possibly associated with interactions.

- SEP events are generally associated with "normal" type II bursts.
- Unusual signatures which might be attributed to interaction are rare (3 clear examples, but could not relate these convincingly to features in LASCO images)
- Radio signatures occurred after SEP onset at 1 AU (SEP onset times in essentially all events most closely associated with type III bursts.)



Identified a few events where the preceding and primary CMEs are from same active region and could be followed out in C2/C3.

For the one event studied in detail (May 9, 1998) with clear evidence of interaction in the LASCO data, there were no radio or SEP signatures that we could associate with this interaction.

Statistical results of Gopalswamy et al. are not inconsistent with a chance association between SEPs and “interacting” CMEs. Problem: small “control group” of wide/fast CMEs without SEPs and/or interaction.

Conclusion: SEP events are very unlikely to be the result of CME interactions.

## *Sub-group 4*

**CME / SEP Injection Timing:** Where is the CME at the onset of SEP injection? What is the relationship between electron (ion) injection onset and the timing of other acceleration signatures, e.g., Type IIIs?

Dennis Haggerty \*  
Bill Dietrich  
George Simnett  
Jie Zhang

Context/Summary: Recently the onset timing of SEP events has received increased attention as a means of discriminating between various acceleration processes. For the workshop, Haggerty, Simnett, and Zhang determined the characteristic height of the CME at the time of the inferred injection onset of ~200 keV electrons for the workshop events. Their result ((~4 Ro) is consistent with more extended studies by Haggerty, Simnett, and Roelof.

## Timing Analysis:

The figure below shows some of the analysis done at the CDAW by comparing the timing of the inferred electron injection to the electromagnetic emissions.

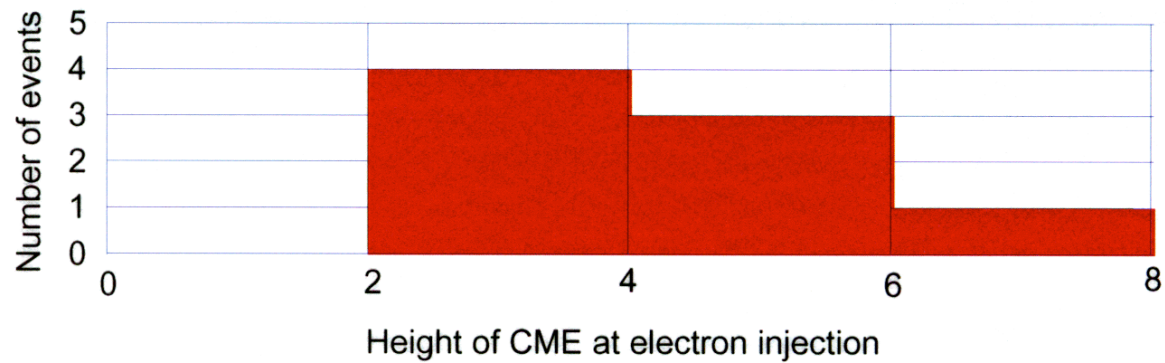
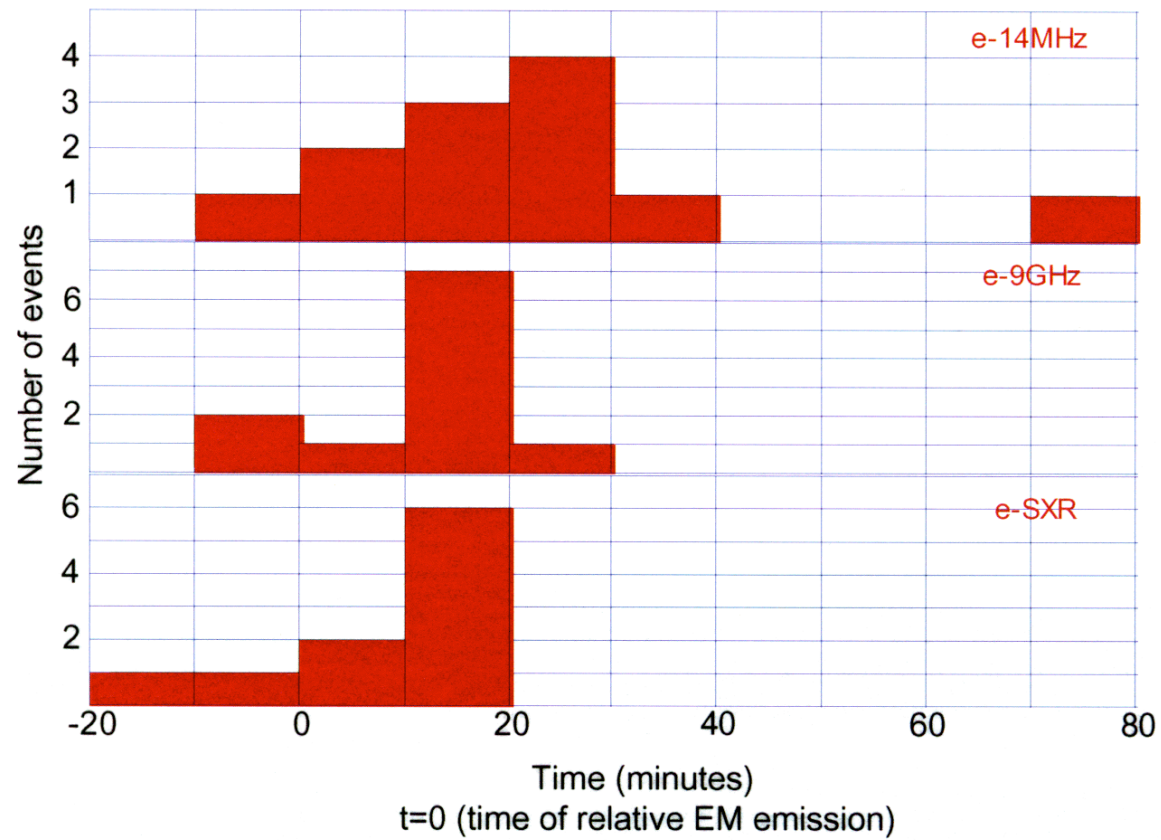
The top plot compares the electron injection at the Sun to the 14 MHz type-III radio emission ( $t=0$ ). This curve shows the electron injection is delayed by something on the order of 20 minutes.

The second curve shows the comparison to the 9 GHz emission and again the delay is observed.

The third curve compares the injection to the start time of the SXR and the delay is once again observed.

The bottom curve shows the injection of the electrons with respect to the height of the CME. The height seems to be between 2 and 6 solar radii.

## CME/SEP Injection timing



## *Sub-group 5*

**SEP Source (non-source) Characteristics:** How are flares/CMEs that produce SEPs distinguished from those that do not? What are the primary characteristics that make a CME or flare produce SEPs? How does shock history affect SEP intensities, spectra, composition?

Ed Cliver \*  
Doug Biesecker  
Hilary Cane  
Sam Freeland  
Peter Gallagher  
Jack Ireland  
James McAteer  
Dalmiro Maia

**Context/Summary:** Traditionally, large SEP events have been characterized by fast coronal mass ejections and shock formation. Cliver and co-workers on this subgroup examined these associations for the workshop events as well as for two sets of control events that lacked associated 20 MeV protons in space and substantiated the earlier CME/type II links to SEP events.

## Association Analysis:

### **Characteristics\* of SEP Sources & Controls**

	<b>W/S Events</b>	<b>Controls</b>
<b>SXR Int</b>	<b>X1</b>	<b>M3</b>
<b>SXR Dur</b>	<b>220 min</b>	<b>65 min</b>
<b>CME Speed**</b>	<b>1350 km/s</b>	<b>915 km/s (27/44)</b>
<b>CME Width**</b>	<b>Halo</b>	<b>80 deg</b>
<b>Metric type II***</b>	<b>84% (26/31)</b>	<b>24% (10/42)</b>
<b>DH type II***</b>	<b>90% (28/31)</b>	<b>5% (2/42)</b>

\*Preliminary

\*\*Median CME Speed & Width

\*\*\*Only Disk Events Considered

## Proposed Changes to Listed Solar Sources\*

<b>No.</b>	<b>Date</b>	<b>Proposed New Source</b>
<b>11</b>	<b>18 Feb 00</b>	<b>&gt;W90</b>
<b>17</b>	<b>28 Jul 00</b>	<b>Interplanetary Shock or Backside Halo on 27<sup>th</sup>?</b>
<b>18</b>	<b>11 Aug 00</b>	<b>Interplanetary Shock</b>
<b>21</b>	<b>25 Oct 00</b>	<b>Backside?</b>
<b>24</b>	<b>26 Nov 00 (1)</b>	<b>25 Nov, M8/0131, N07E50</b>
<b>25</b>	<b>26 Nov 00 (2)</b>	<b>Modulation?</b>
<b>34</b>	<b>07 May 01</b>	<b>&gt;W90?</b>
<b>36</b>	<b>09 Aug 01</b>	<b>C8/1834, S11E19(?)</b>
<b>48</b>	<b>30 Dec 01</b>	<b>Modulation?</b>

\*Preliminary

## Synopsis:

### Key Results From Solar Sources Group

- 1) High (~65%) association of  $^3\text{He}$ -rich events with CMEs; marked departure from current picture. Caveats: These are “large”, well-defined  $^3\text{He}$ -rich SEP events. The CME association might be a type of Big Flare Syndrome effect observed in small flares. Are the CMEs essential or peripheral to the SEP acceleration? Many of the identified CMEs were not included in the original LASCO list. Are we changing the definition of CMEs? Implication for CME rates?
- 2) Large SEP events are highly associated with fast CMEs, type II bursts, and type III L's. The Type III L association suggests that flares contribute to these proton events. The relative contributions of flares and shocks to large SEP events is a central question in SEP physics.
- 3) While large SEP events are highly associated with (apparently) interacting CMEs, the significance of CME interaction for SEP acceleration is debatable.



- 4) Much of the discussion and interest in the workshop revolved around the Type A (exponential spectra) and Type B (power law) classes of SEP events identified independently by Cohen and Tylka in the CDAW data base. Part of the on-going charter of the sources group was to look for different solar signatures for these two classes of events. Signatures that need to be considered include such factors as flare duration and height of shock formation. It seems likely, however, that flare/CME location also plays an important role. For example, there is a preference for the Type B events to be well-connected. Well-equipped multi-spacecraft missions such as STEREO will be needed to address this basic acceleration/propagation question.